# Serendipitous Discovery of a Cataclysmic Variable in the Globular Cluster NGC 6624 [1]

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## ABSTRACT

Despite indications that classical cataclysmic variable (CV) stars are rare in globular clusters in general, and in the cluster NGC 6624 in particular, we have serendipitously discovered such a star $\sim 6''$ from the cluster center. A *Hubble Space Telescope* spectrum of the $m \sim 22$ object shows strong, broad emission lines typical of numerous field CVs, and the inferred optical and UV luminosity are also similar. Our accidental observation also provides the first high-quality ultraviolet spectrum of a globular cluster CV. That we have detected such an object in an observation that includes just a few percent of the central area of the cluster may indicate that cluster CVs are more common than previously thought, at least near the core.

*Subject headings:* binaries: close — globular clusters: individual (NGC 6624) — novae, cataclysmic variables

## 1. INTRODUCTION

A small number of close binary stars are thought to dominate the dynamic evolution of many globular star clusters (Hut et al. 1992, Bailyn 1995), yet classes of such objects which are relatively easily found in the field have proven frustratingly difficult to discover in clusters. A prime example is cataclysmic variables (CVs), which call attention to themselves via large amplitude light outbursts, and peculiar, ultraviolet-excess colors in quiescence. With quiescent absolute magnitudes $M_V \sim 7-8$, modern ground-based photometric techniques should easily uncover such objects in clusters with typical distances of $(m-M) \sim 14$, even with modest telescopes, unless

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all such objects are lost to the crowded cores. Yet prior to the launch of *Hubble Space Telescope* (*HST*), we are aware of only two candidate identifications of CVs in globular clusters, M5 V101 (Margon et al. 1981), whose classification and cluster membership seems secure (Naylor et al. 1989, Shara et al. 1990), and M30 V4 (Margon & Downes 1983), whose membership is unclear (Shara et al. 1990, Machin et al. 1991).

Observations from *HST* have certainly improved the situation, although perhaps not as much as many would have expected. A few clusters are now known to have a handful of spectroscopically-confirmed CVs; a recent review is given by Grindlay (1999). However despite intensive photometric and color-selected searches deep into the cores of a number of clusters, few outbursting objects are found, and most authors believe there is a serious discrepancy with theoretical predictions (Shara & Drissen 1995; Livio 1996; Shara et al. 1996, hereafter S96). Whether the problem lies with formation/destruction rates, or some unique property of cluster CVs, remains to be clarified, and will surely require a larger sample of objects.

Here we discuss *HST* observations of the cluster NGC 6624 using the *Space Telescope Imaging Spectrograph* (STIS). This cluster contains near its center a highly luminous bursting X-ray source with an 11-minute period, the shortest-known binary star; the system is thought to be a double-degenerate (Stella et al. 1987, King et al. 1993, Anderson et al. 1997). Another object in the cluster has also been suggested by S96 as a candidate CV, although we discuss its nature further in §3. As part of a program to study the central bright X-ray source, we obtained deep STIS spectroscopic exposures of this object, and these results will be discussed elsewhere (Deutsch et al. 2000). Here we report the completely serendipitous discovery of $m \sim 22$ emission line object, which fell by good fortune in the STIS slit, and has the properties of a classical CV. This object deepens the mystery of the CV content of clusters. S96 report a multi-epoch sensitive photometric search of the core of NGC 6624 which identifies only one candidate CV, and suggest these objects are very rare, at least in this cluster. Yet we have found another such an object completely by accident, in the first long-slit ultraviolet spectral exposure made of the cluster.

## 2. OBSERVATIONS AND ANALYSIS

### 2.1. STIS Spectra

On 1998 March 14 we obtained 12150 s of integration in the center of NGC 6624 over 5 orbits with the *HST* STIS FUV-MAMA, using a $0\farcs5$ wide, $23''$ long slit. The spectra are reprocessed and extracted using CALSTIS 2.0 and the latest calibration files available as of 1999 April 20, where nearly half of the calibration files are updated from the original pipeline processing.

In Fig. 1 we show a $10''$ long region of the cluster spectrum, which has been background subtracted for display purposes. The primary target, the X-ray source hereafter denoted Star K, is clearly visible at the top. Two other objects, labeled Stars 1 and 2, are visible. No other objects are discernible in the entire long-slit spectrum, including the region not shown in Fig. 1.

The extracted spectrum of Star 1, binned 2× to 1.17 Å per bin, is displayed in Fig. 2. Strong, broad emission lines of N V $\lambda\lambda$1238,1242, Si IV $\lambda\lambda$1394,1403 and/or O IV] $\lambda$1401, C IV $\lambda\lambda$1548,1550, and He II $\lambda$1640 are clearly detected. The O I $\lambda$1304 feature is most likely imperfectly subtracted geocoronal emission. The location of a few other common emission lines

which may contribute to this spectrum are also marked. The continuum is very weakly detected at $(0.4 \pm 0.2) \times 10^{-17}$ erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$. This spectrum is that of a classical cataclysmic variable in a quiescent state (e.g., Wu et al. 1992). We show in §3 that both the optical and UV magnitudes of the object agree with those expected for a CV at the distance of the cluster, and the probability of a chance superposition of a non-member within $6''$ of the cluster core is small. We conclude that we have serendipitously discovered a CV in the cluster.

We have attempted to independently verify cluster membership via radial velocity measurements of the spectrum, but the results are inconclusive. We were forced to use an undesirably large slit width due to potential problems in target acquisition in this complex field, and the resulting configuration is poorly suited for absolute velocity determinations. If we accept the nominal CALSTIS wavelength calibration, the inferred radial velocity, obtained from several strong emission lines, is $-600$ km s$^{-1}$. The uncertainty in this value is however dominated by the zero point error introduced by the unknown location of the object within the slit, which could be as large as $\pm 1,200$ km s$^{-1}$, so the constraint is not meaningful. Further, we expect the radial velocity of the star to vary, with unknown period and probably large amplitude, and so cannot make a cogent estimate of the mean velocity after one observation. We have also searched for radial velocity variations from orbit to orbit, again with inconclusive results due to large uncertainties in the subsets of the data.

The spectrum of Star 2 is a flat continuum of $(1.7 \pm 0.2) \times 10^{-17}$ erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$, and featureless except for possible detections of the common interstellar absorption lines Si II $\lambda$1260, C II $\lambda\lambda$1334,1335, and C IV $\lambda\lambda$1548,1551. When dereddened, the spectrum and photometry are reasonably well described by a Kurucz model (Kurucz 1992) of $T_{eff}$ = 14,000 K and $M_V \sim 6.5$. This is consistent with the properties of the non-flickering "NF" objects discussed by Cool et al. (1998) and Edmonds et al. (1999).

### 2.2. WFPC2 and FOC Imagery

We attempt to determine the precise location of the objects seen in our spectroscopic observations by examining archival *HST* images. We find F140W and F430W (pre-COSTAR) FOC images taken on 1992 August 13 which cover this field, as well as WFPC2 images taken on 1994 April 17 and 1994 October 15, obtained with a variety of filters. There exist two additional epochs of WFPC2 data, but as this field falls on the lower resolution Wide Field Camera CCDs in those observations, they provide no additional useful information.

Given the crowding in the cluster core, determination of which objects are responsible for the observed spectra is not trivial. Based on information in the STIS header, the distance of Stars 1 and 2 from the bright Star K is $4\farcs66$ and $6\farcs34$, respectively, at a position angle of 41°. In Fig. 3 we show $5''\times5''$ regions of the various FOC and WFPC2 images. Overlaid are two arcs indicating the calculated radii of these objects from Star K (not present in this field). The nearly horizontal lines indicate the edges of a $0\farcs5$ slit. Therefore, we expect to find the objects responsible for the spectra near the intersections of the arcs and the slit. Residual uncertainty in the slit angle is less than 1° and thus not important at this scale. Finally, the figure assumes that Star K is centered on the slit. If Star K is in fact shifted slightly in the slit, then the location of the slit we have drawn may be displaced up or down by up to $0\farcs25$; the target acquisition scenario employed

should place Star K very near the center of the slit, however.

In the 1400 Å FOC image, we find a faint object at the expected location of Star 2, and label it Star B (recognizing that the association is hardly guaranteed.) We find no evidence for any detection at the expected location of Star 1 in this F140W image. Examining successively longer wavelength images, we find that star B exhibits UV-excess between the F336W and F439W images, but is hopelessly contaminated by light from neighboring stars at longer wavelengths. At the expected location of Star 1, we find a faint star which we label A at F439W and longer wavelengths, although there is no evidence of it at F336W and F140W. Star A is positively detected at multiple epochs as well as multiple wavelengths, although it falls just outside the FOC F430W image. There is also another faint object $0\farcs15$ NW of Star A, which is also a plausible candidate. No small adjustments in slit angle or slit shift yield a better alignment. In the astrometric frame of *HST* image U2AS0101T, the coordinates for Star A are $\alpha(2000) = 18^{\rm h}23^{\rm m}40\fs810$, $\delta(2000) = -30°21'35\farcs01$. Although internally precise, this position has a probable uncertainty of $\sim 1-2''$ with respect to external frames. Based on our estimate of the cluster center in the same image, we find that Star A is $6\farcs5$, or 1.8 core radii, from the center of NGC 6624 (assuming $r_c = 3\farcs6$ from Harris 1996). A detailed discussion of a precise measurement of the cluster center, not relevant to our analysis, is given by King et al. (1993). Two radio pulsars are located within $\sim 10''$ of Star A (Biggs et al. 1994), but the positions are definitely disjoint, given the quoted uncertainties. In a cluster of $r_c = 3\farcs6$, it is perhaps not surprising that multiple interesting but unrelated objects are in such proximity.

In Table 1 we present photometry for selected objects in the field. We use a combination of profile-fitting and aperture photometry to derive these magnitudes. For WFPC2 images, aperture corrections are taken from Table 2(a) in Holtzman et al. (1995b). The photometric measurements have not been corrected for geometric distortions, nor is any correction for charge transfer efficiency losses (Holtzman et al. 1995b) applied; for most of the images, these effects should contribute errors of only a few percent. We use the photometric zero points for the STMAG system from Table 9 ($Z_{STMAG}$) in Holtzman et al. (1995a). Approximate $1\sigma$ measurement uncertainties are also provided in the table. Systematic errors for all magnitudes due to uncertainties in detector performance and absolute calibration are $\sim$5%. Magnitude measurements presented here are denoted $m_\lambda$, where $\lambda$ is the filter designation, approximately indicating the central wavelength of the filter in nanometers. In the STMAG system, zero points are set such that a flat spectrum ($f_\lambda =$ constant) source will have identical magnitudes at all wavelengths.

For the FOC measurements, we use the calibration provided in the header of the images. A STSDAS *synphot* calculation yields a calibration value which differs by $\sim 30\%$. We use a Tiny TIM (Krist 1993) synthetic profile to determine an aperture correction. Since the F140W images were obtained in an unusual mode and far UV calibration is often difficult in any case, we suspect that the absolute calibration may not be accurate to better than a factor of two.

In order to further check that the associations between Stars 1 and A, and Stars 2 and B, are plausible, we estimate $m_{140}$ for Stars 1 and 2 at the time of the STIS observations by convolving the spectra with the F140W bandpass and integrating the observed flux. We estimate $m_{140} = 22.2$ for Star 1, and $m_{140} = 20.9$ for Star 2, and estimate uncertainties of 0.2 mag principally because the spectra do not fully cover the F140W bandpass. Given the various uncertainties in this estimate and FOC calibration, the agreement between the STIS and FOC (Table 1) magnitude estimates is excellent. Aside from the observed level of excitation in the spectrum, the lack

of any brighter and/or spatially extended image near the correct location for Star 1 provides confirmation that the observed emission spectrum cannot be due to a cluster planetary nebula or the background superposition of a low redshift AGN. We conclude that Star A is the likely source of the emission line spectrum.

We point out in passing yet another unusual object in the same field. Star C (Table 1, Fig. 3) is extremely bright in these F140W images, but a rather faint object in longer wavelength passbands. When dereddened, the $m_{140}$, $m_{336}$, and $m_{439}$ measurements are well fit by a Kurucz model of $T_{eff}$ = 35,000 K. This temperature is most sensitive to the F140W measurement for which the calibration is poorest. If the FOC calibration is adjusted by 0.4 mag such that the FOC observed and STIS convolved magnitudes are equal for Star B, the implied temperature for Star C is $T_{eff}$ = 30,000 K. This extraordinary UV excess is noteworthy but otherwise not relevant to the present discussion, except as further evidence of a multitude of exotic objects near the center of this cluster.

## 3. DISCUSSION

Our photometry in §2.2 together with the known distance and reddening of the cluster permit a comparison of the luminosity of this object with that of the far better-studied field CVs. Adopting $(m - M)_0 = 14.50$ and $E(B - V) = 0.28$ (Harris 1996), our measured $m_{555} = 21.8$ implies $M_V \sim 6.5$. There are now four trigonometric parallaxes for classical field CVs (Harrison et al. 1999, McArthur et al. 1999), which collectively imply $< M_{V,min} \sim 8.0 >$, similar to the $< M_{V,min} \sim 7.5 >$ often quoted from much larger samples (Warner 1995). Given the uncertainties in our photometry for this faint object in a very crowded field, and our single-epoch measurement of an undoubtedly variable star, the agreement of the inferred luminosity of the new NGC 6624 CV with those in the field is gratifying. If the system is strongly magnetic, a possibility we consider below, our observed magnitude is perhaps somewhat brighter than expected from polars in the field, but, again given the uncertainties, not alarmingly so.

We are aware of few if any ultraviolet spectra of globular cluster CVs. Edmonds et al. (1999) display a low signal-to-noise spectrum of an object in NGC 6397, where He II $\lambda$1640 is termed "marginally detected" in emission by those authors. Through absolutely no credit to the current authors, our spectrum is far better exposed.

The prominent He II $\lambda$1640 emission in our spectrum is deserving of comment. This line is normally not strong in classical CVs, but is seen in polars. Our spectrum is indeed quite similar to that of AM Her in this wavelength range (Greeley et al. 1999). Unfortunately the simplest defining spectroscopic characteristic of AM Her stars, very strong He II $\lambda$4686 emission, is not accessible to us. Although little can be inferred from one object, we note that Grindlay et al. (1995) have suggested that magnetic white dwarfs are preferentially produced in globular clusters (see also Grindlay 1999 and references therein). These authors also discuss the issue of possible confusion of the spectra of cluster CVs with those of quiescent low-mass X-ray binaries (LMXBs), and those considerations also apply here. Our spectrum does not unambiguously distinguish between the two cases; for example, the quiescent LMXB Cen X-4 (V822 Cen) shows quite weak He II $\lambda$4686 (McClintock & Remillard 1980) and little or no $\lambda$1640 emission (Blair et al. 1984), but Aql X-1 (V1333 Aql) displays strong He II $\lambda$4686 in quiescence (Garcia et al. 1999). As more

CVs than quiescent LMXBs are known in clusters, it seems most conservative, but still uncertain, to continue the discussion of CVs. As this object lies only a few arcsec from the brightest X-ray source in any globular cluster, its X-ray properties are as yet unknown, but may be accessible to observations from *Chandra*.

Although our detection of the ultraviolet continuum is weak, it is of interest to ask if the observed ultraviolet flux agrees with that expected from the field objects, as we have determined above is the case for the visible band. If we assume $A_{135\mathrm{nm}} = 9\,E_{B-V}$ (Cardelli et al. 1989), our observed $f_\lambda(135) \sim 0.5 \times 10^{-17}$ erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$ corresponds to an extinction-corrected monochromatic luminosity of $L_\lambda(135) \sim 3 \times 10^{29}$ erg s$^{-1}$ Å$^{-1}$. For the quiescent U Gem, for example, $f_\lambda(135) \sim 1.5 \times 10^{-13}$ erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$ (Wu et al. 1992, Long et al. 1994, Long & Gilliland 1999); this ratio of 30,000 in observed fluxes speaks well to advances in ultraviolet spectroscopic capabilities from the *International Ultraviolet Explorer* (*IUE*) to the *HST* era. Adopting $d = 100$ pc (Harrison et al. 1999) and $E(B-V) = 0.03$ (Panek and Holm 1984, Long & Gilliland 1999) for U Gem, we infer $L_\lambda(135) \sim 2 \times 10^{29}$ erg s$^{-1}$ Å$^{-1}$ for that object. While this excellent level of agreement is almost surely fortuitous, it reaffirms that the CV in NGC 6624, with the exception of its unusual environment, seems a totally normal cataclysmic. As various abnormal mass transfer scenarios have been at times invoked to explain the lack of cluster CV outbursts, this agreement is interesting.

There is one previous candidate for a CV in NGC 6624, as discussed by S96. The identification was based on the presence of the object on two consecutive *HST* images, but its absence in all other observations. We have recovered the candidate in the archival *HST* images, and derive its position as $\alpha(2000) = 18^{\mathrm{h}}23^{\mathrm{m}}41^{\mathrm{s}}.349$, $\delta(2000) = -30^\circ 21' 56''.53$ using the astrometric header information in *HST* image U2KL0406T. This position is $\sim 25''$ from Star A, and thus this object cannot be responsible for our spectrum.

Moreover, upon close examination of these data, we find that the radial profile of this object is not compatible with a stellar one. We suggest it is an image artifact of uncertain origin. In Fig. 4, we show a surface plot of the pixels around this object and a nearby, typical star of similar total counts. The S96 object has a profile much too sharp as compared with this and other stars. It is indeed detected in two frames, and thus is not a charged particle hit, but rather probably a group of hot pixels or calibration file defect. We stress however that the removal of the S96 object from the list of cluster CVs merely *strengthens* the primary scientific conclusion of that paper, namely that erupting CVs are remarkably rare in clusters.

## 4. CONCLUSION

We have serendipitously discovered a mass-transfer close binary, presumably with a degenerate companion, close to the core of NGC 6624. It is likely that the system is a classical cataclysmic variable, although a quiescent LMXB cannot be ruled out. The situation is a curious inversion of the normal problem in globular cluster observations, where one finds an interesting star but has difficulty obtaining the spectrum due to severe crowding. We have easily obtained the spectrum, but are uncertain of which object is responsible for the emission, although we advance as a reasonable candidate Star A. The uncertainty in the exact coordinates of the system does not however change the surprising result that an object supposedly so rare has been found accidentally.

The object was found in a single STIS long-slit exposure encompassing $\sim 12$ arcsec$^2$ at an arbitrary position angle passing quite close to the cluster center. A hypothetical observing program that included all possible position angles with this slit, thus completely mapping the cluster center to $r = 3\,r_c$, would cover $\sim 30\times$ more area. Tempered by the usual uncertainties of *a posteriori* statistics, it seems quite likely that the center of NGC 6624 contains several, and possibly many, more CVs of the type we have discovered here. If we now accept that these systems most certainly are present — as has indeed been theoretically expected for some time — then one or more mechanisms which suppress the expected outbursts and/or odd colors, and thus hide globular cluster CVs, must certainly be operative.

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## REFERENCES

Anderson, S. F., Margon, B., Deutsch, E. W., Downes, R. A., & Allen, R. G. 1997, ApJ, 482, L69

Bailyn, C. D. 1995, ARA&A, 33, 133

Biggs, J. D., Bailes, M., Lyne, A. G., Goss, W. M., & Fruchter, A. S. 1994, MNRAS, 267, 125

Blair, W. P., Raymond, J. C., Dupree, A. K., Wu, C-C., Holm, A. V., & Swank, J. H. 1984, ApJ, 278, 270

Cardelli, J. A., Clayton, G. C., & Mathis, J. S. 1989, ApJ, 345, 245

Cool, A. M., Grindlay, J. E., Cohn, H. N., Lugger, P. M., & Bailyn, C. D. 1998, ApJ, 508, L75

Deutsch, E. W., Margon, B., & Anderson, S. F. 2000, in preparation

Edmonds, P. D., Grindlay, J. E., Cool, A., Cohn, H., Lugger, P., & Bailyn, C. 1999, ApJ, 516, 250

Garcia, M. R., Callanan, P. J., McCarthy, J. M., Eriksen, K., & Hjellming, R. M. 1999, ApJ, 518, 422

Greeley, B. W., Blair, W. P., Long, K. S., & Raymond, J. C. 1999, ApJ, 513, 491

Grindlay, J. E. 1999, in ASP. Conf. Ser. 157, Annapolis Workshop on Magnetic Cataclysmic Variables, ed. C. Hellier & K. Mukai (San Francisco: ASP), 377

Grindlay, J. E., Cool, A. M., Callanan, P. J., Bailyn, C. D., Cohn, H. N., & Lugger, P. M. 1995, ApJ, 455, L47

Harris, W. E. 1996, AJ, 112, 1487

Harrison, T. E., McNamara, B. J., Szkody, P., McArthur, B. E., Benedict, G. F., Klemola, A. R., & Gilliland, R. L. 1999, ApJ, 515, L93

Holtzman, J. A., Burrows, C. J., Casertano, S., Hester, J. J., Trauger, J. T., Watson, A. M., & Worthey, G. 1995a, PASP, 107, 1065

Holtzman, J. A., et al. 1995b, PASP, 107, 156

Hut, P. et al. 1992, PASP, 104, 981

King, I. R. et al. 1993, ApJ, 413, L117

Krist, J. 1993, in ASP Conf. Ser. 52, Astronomical Data Analysis Software and Systems II, ed. R. J. Hanisch, R. J. V. Bissenden, & J. Barnes (San Francisco: ASP), 530

Kurucz, R. L. 1992, in IAU Symposium No. 149, The Stellar Population of Galaxies, ed. B. Barbuy & A. Renzini (Dordrecht: Kluwer), 225

Landsman, W. B. 1993, in ASP Conf. Ser. 52, Astronomical Data Analysis Software and Systems II, ed. R. J. Hanisch, R. J. V. Bissenden, & J. Barnes (San Francisco: ASP), 256

Livio, M. 1996, in ASP. Conf. Ser. 90, The Origins, Evolutions, and Destinies of Binary Stars in Clusters, ed. E. F. Milone & J.-C. Mermilliod (San Francisco: ASP), 312

Long, K. S., & Gilliland, R. L. 1999, ApJ, 511, 916

Long, K. S., Sion, E. M., Huang, M., & Szkody, P. 1994, ApJ, 424, L52

Machin, G. et al. 1991, MNRAS, 250, 602

Margon, B., Downes, R. A., & Gunn, J. E. 1981, ApJ, 247, L89

Margon, B., & Downes, R. A. 1983, ApJ, 274, L31

McArthur, B. E. et al. 1999, ApJ, 520, L59

McClintock, J., & Remillard, R. 1990, ApJ, 350, 386

Naylor, T. et al. 1989, MNRAS, 241, 25p

Panek, R. J., & Holm, A. V. 1984, ApJ, 277, 700

Shara, M. M., & Drissen, L. 1995, ApJ, 448, 203

Shara, M. M., Moffat, A. F. J., & Potter, M. 1990, AJ, 99, 1858

Shara, M. M., Zurek, D. R., & Rich, R. M. 1996, ApJ, 473, L35 (S96)

Stella, L., Priedhorsky, W., & White, N. E. 1987, ApJ, 312, L17

Warner, B. 1995, Cataclysmic Variable Stars (Cambridge: Cambridge Univ. Press)

Wu, C.-C. et al., 1992, International Ultraviolet Explorer Ultraviolet Spectral Atlas of Selected Astronomical Objects, NASA Reference Publication 1285

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Table 1. Photometry of Selected Objects in NGC 6624

| Object | $m_{140}$ | $\sigma$ | $m_{336}$ | $\sigma$ | $m_{439}$ | $\sigma$ | $m_{555}$ | $\sigma$ |
|---|---|---|---|---|---|---|---|---|
| Star A [a] | $> 21.6$ | ··· | $> 23.0$ | ··· | 22.2 | 0.5 | 21.8 | 0.3 |
| Star B | 20.5 | 0.2 | 21.5 | 0.2 | 21.2 | 0.3 | $> 21.5$ | ··· |
| Star C | 19.2 | 0.1 | 21.3 | 0.2 | 21.8 | 0.3 | $> 21.5$ | ··· |

[a] suggested identification of the spectroscopically-discovered cataclysmic variable

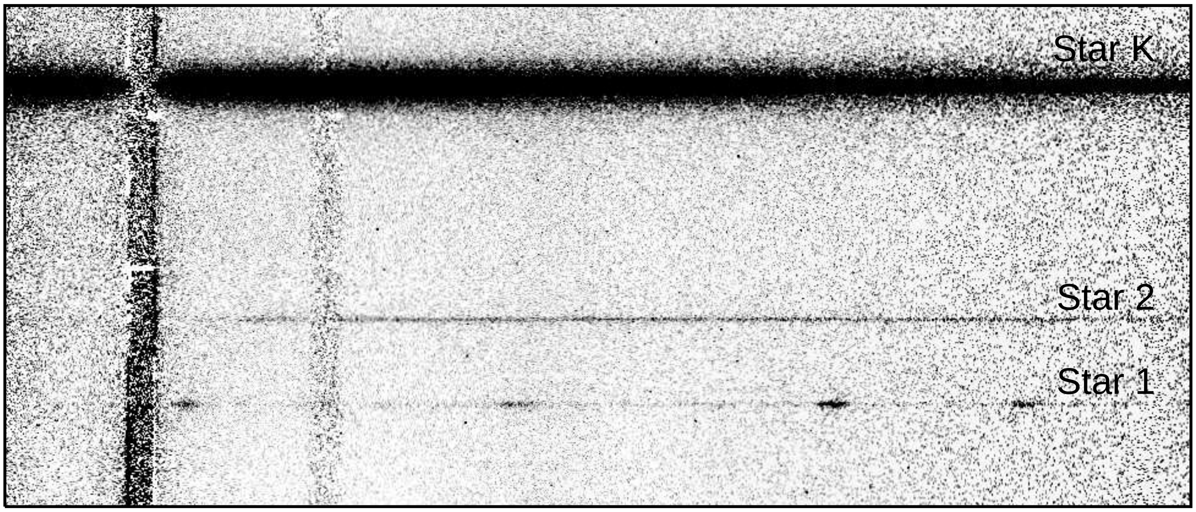


Fig. 1.— 550 Å × 10″ *HST* STIS long slit spectrum of the core of NGC 6624. The low-mass X-ray binary optical counterpart, Star K, is most prominent at the top. Star 1 is a cataclysmic variable with broad emission lines. Star 2 is a UV-excess, featureless object also discussed in the text. The background has been subtracted in this image and the two vertical bands are residuals from subtracted geocoronal Ly $\alpha$ and O I $\lambda$1304 emission. The N V $\lambda\lambda$1238,1242, Si IV $\lambda\lambda$1394,1403, C IV $\lambda\lambda$1548,1550, and He II $\lambda$1640 emission in Star 1 is clearly visible.

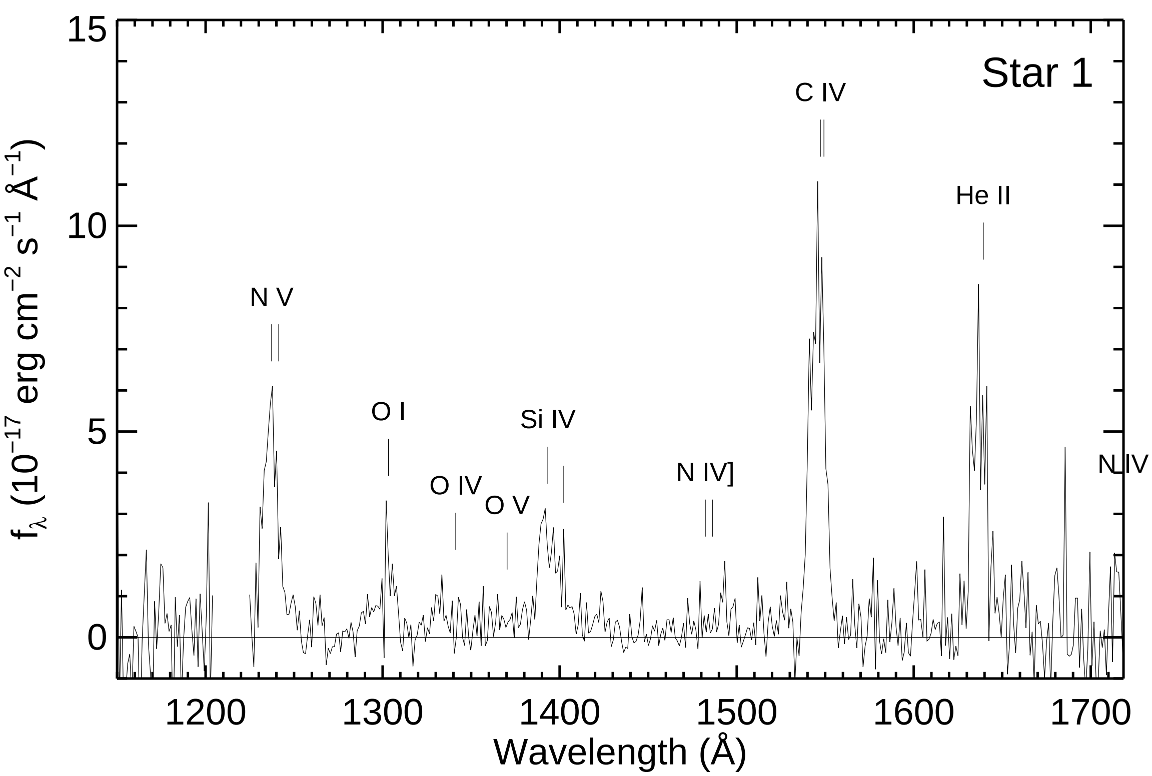


Fig. 2.— The extracted, flux-calibrated *HST* STIS spectrum for the newly discovered cataclysmic variable in NGC 6624. Geocoronal Ly $\alpha$ badly mars the spectrum and has been deleted; the residual O I $\lambda$1304 emission is probably also geocoronal.

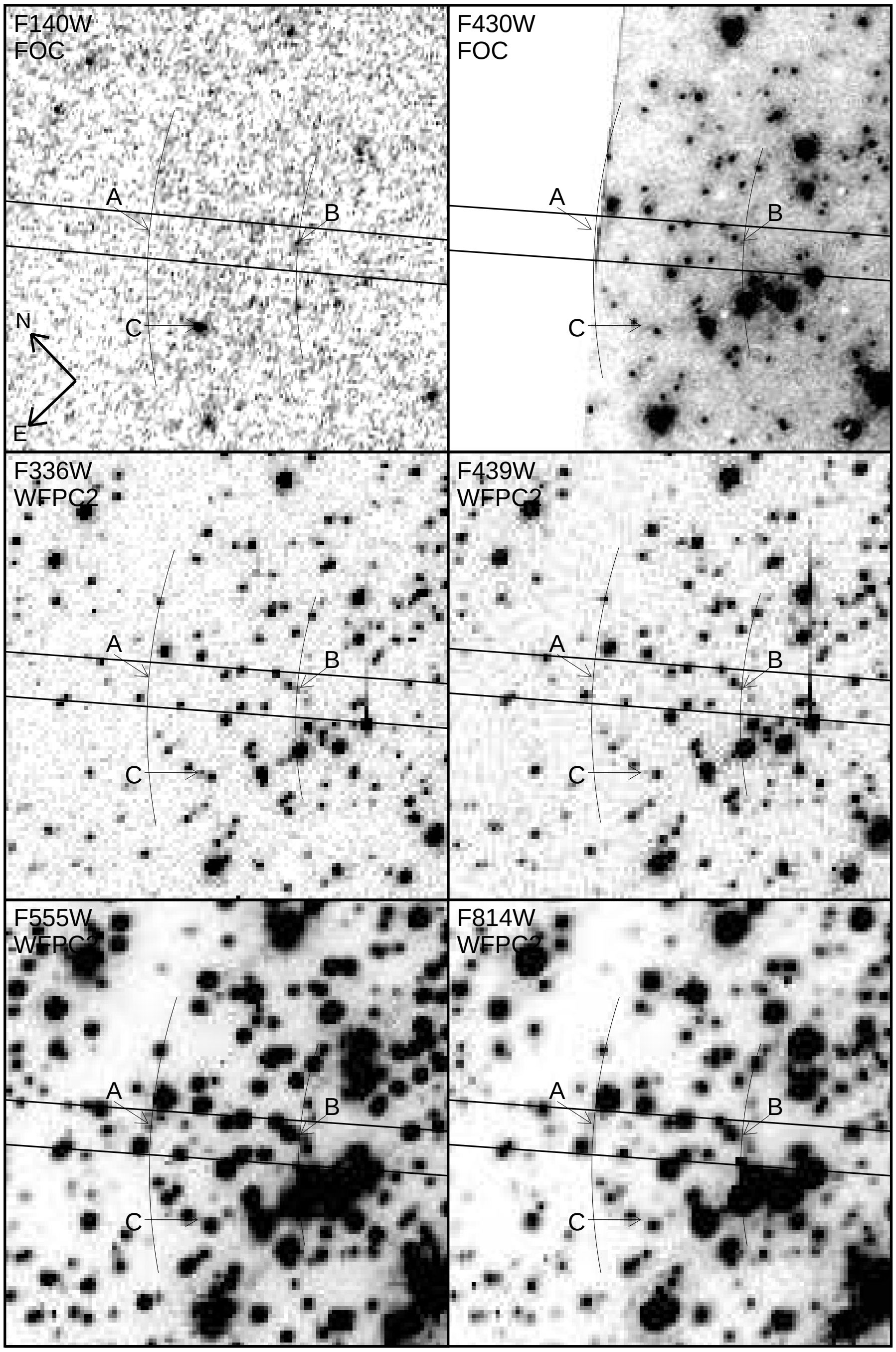


Fig. 3.— $5'' \times 5''$ field near the location of the STIS spectra in NGC 6624. Each left/right pair of archival exposures was obtained at the same epoch. The two arcs represent the distances of our two spectra from Star K (not itself in this field). The two nearly horizontal lines represent the STIS $0\farcs5$ slit; thus the spectra discussed here must arise from objects on or very near the arcs, and within the slit. Note the rotated cardinal direction. Various objects discussed in the text are labeled. We suggest that Star A is the optical counterpart to the cataclysmic variable spectrum displayed in Fig. 2.

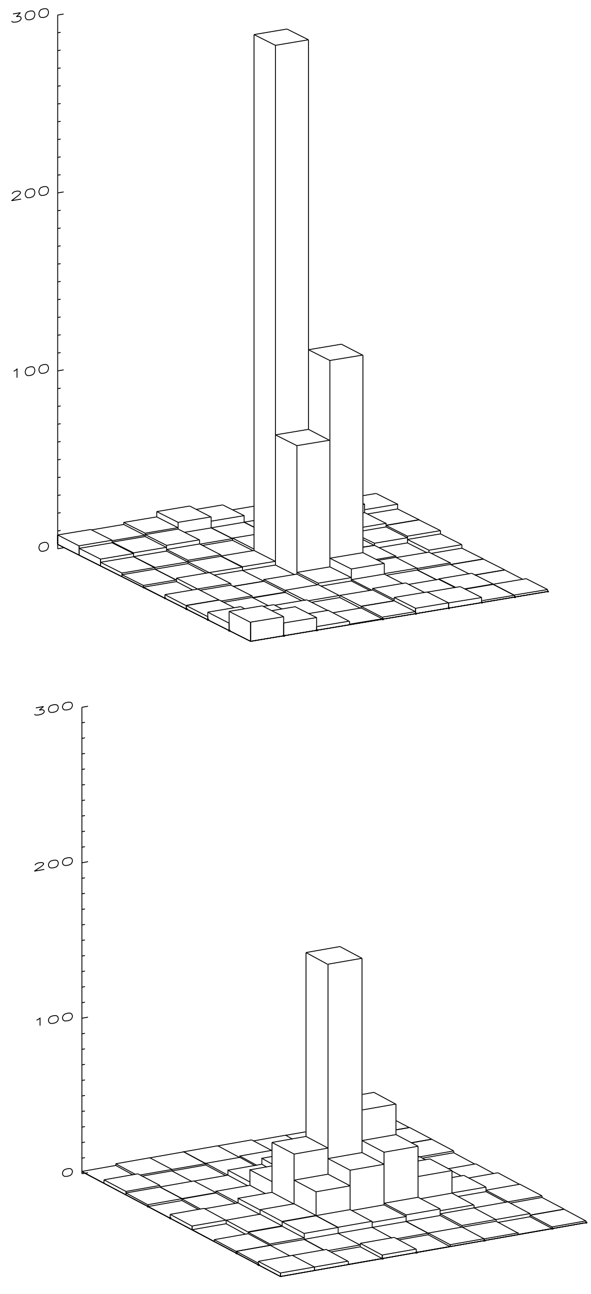


Fig. 4.— (*top*) Surface plot of the Shara et al. (1996) NGC 6624 dwarf nova candidate. Each block is one individual pixel on the *HST* Wide Field Camera detector image U2KL0406T. (*bottom*) Surface plot of a nearby star which has similar total flux within a 3 pixel radius. The Shara et al. object is much sharper than a normal stellar profile, and likely an image artifact.